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(54) Title of the invention: Positioning Device, Alignment Device, and Positioning Method

(57) Abstract (corrected)

Purpose: To support, position, and control an object such that reaction forces and vibrations created by movement of the object are not transferred to other elements like a lens system.

Configuration: A reaction frame 61 is provided which isolates both external vibrations as well as vibrations caused by reaction forces from an object stage 30. The object stage moves in two directions. A reaction frame includes two followers. Cooperating linear force actuators are mounted on the object stage and the followers for positioning the object stage in the first and second directions. The reaction frame is mounted on a base structure and the object stage is supported in space independent of the reaction frame. A follower 72 has a pair of arms 74, 74' and moves in a pair of parallel planes with the center of gravity of the object stage therebetween. The positioning forces of actuator drive means are controlled so that a vector sum of moments of force at the center of gravity of the object stage is substantially equal to zero.

Scope of Patent Claims

Claim 1

A positioning device operative on a base structure, comprising:

(a) a reaction frame assembly including a reaction frame mounted to the base structure;

(b) an object stage movable relative to an object stage base;

(c) means for supporting the object stage from the object stage base with a gap therebetween, independently of the reaction frame; and

(d) a pair of cooperating linear actuator means mounted to the object stage and the reaction frame assembly for positioning the object stage and generating a force,

wherein the object stage base and the object stage are isolated from a reaction force from the actuator means, thereby minimizing transfer of vibrations to the object stage base and the object stage.

Claim 2

The positioning device according to claim 1, wherein the reaction frame assembly includes a follower which is movable independently of the object stage to be followed.

Claim 3

The positioning device according to claim 1, wherein the actuator means includes at least one linear motor which operates between the object stage and the reaction frame assembly.

Claim 4

The positioning device according to claim 1, wherein at least one set of actuator means for positioning the object stage are provided, and each actuator means includes a drive member mounted to the object stage.

Claim 5

The positioning device according to claim 4, wherein a vector sum of the moments of force at the center of gravity of the object stage due to positioning forces of the drive member is substantially equal to zero.

Claim 6

The positioning device according to claim 2, further comprising at least one drive member mounted to the object stage.

Claim 7

The positioning device according to claim 2, wherein the follower includes two arms movable respectively in two parallel planes, and the center of gravity of the object stage is located between the two planes.

Claim 8

The positioning device according to claim 1, wherein the object stage is movable at least in a first direction and a second direction forming an angle with the first direction, a first follower is movable only in a first direction and follows the object stage, a second follower is movable only in a second direction and follows the object stage, and the cooperating actuator means are provided in the object stage and the first and second followers and positions the object stage in the first and second directions.

Claim 9

The positioning device according to claim 8, wherein the actuator means include at least three linear actuators generating forces, which operate between the object stage and the reaction frame assembly.

Claim 10

The positioning device according to claim 9, wherein two of the at least three linear actuators are provided so as to drive the object stage in the first direction and a vector sum of the moments of force at the center of gravity of the object stage due to positioning forces of the cooperating actuator means is substantially equal to zero.

Claim 11

The positioning device according to claim 10, wherein one of the linear actuators other than the two linear actuators is mounted to the object stage so as to drive the object stage in the second direction and a vector sum of the moments of force at the center of gravity of the object stage due to positioning forces of the cooperating actuator means is substantially equal to zero.

Claim 12

The positioning device according to claim 8, wherein at least two sets of linear actuators for positioning the object stage are provided, one set of the linear actuators positions the object stage in the first direction, another one set of the linear actuators positions the object stage in the second direction, and a vector sum of the moments of force at the center of gravity of an XY stage due to positioning forces of the cooperating actuator means is substantially equal to zero.

Claim 13

The positioning device according to claim 8, wherein the first and second followers include two spaced-apart arms, respectively, the arm of one follower is positioned and movable in a single plane, and the arm of the other follower is positioned and movable in two parallel planes with the single plane therebetween.

Claim 14

The positioning device according to claim 13, wherein the center of gravity of the object stage is positioned in the single plane or adjacent to the single plane.

Claim 15

A positioning device comprising:

(a) an object stage at least moving in a first direction and a second direction forming an angle with the first direction;

(b) a first follower movable only in the first direction and following the object stage;

(c) a second follower movable only in the second direction and following the object stage; and

(d) cooperating linear force actuator means mounted to the object stage and the first and second followers for positioning the object stage in the first and second directions.

Claim 16

The positioning device according to claim 15, wherein the actuator means includes at least three linear force actuators, which operate between the object stage and each of the followers.

Claim 17

The positioning device according to claim 16, wherein two of the at least three linear actuators are provided so as to drive the object stage in the first direction and a vector sum of the moments of force at the center of gravity of the object stage due to positioning forces of the cooperating actuator means is substantially equal to zero.

Claim 18

The positioning device according to claim 17, wherein one of the linear actuators other than the two linear actuators is mounted to the object stage so as to drive the object stage in the second direction and a vector sum of the moments of force at the center of gravity of the object stage due to positioning forces of the cooperating actuator means is substantially equal to zero.

Claim 19

The positioning device according to claim 15, wherein at least two sets of linear actuators for positioning the object stage are provided, one set of the linear actuators positions the object stage in the first direction, another one set of the linear actuators positions the object stage in the second direction, and a vector sum of the moments of force at the center of gravity of the object stage due to positioning forces of the cooperating actuator means is substantially equal to zero.

Claim 20

The positioning device according to claim 15, wherein the first and second followers include two spaced-apart arms, respectively, the arm of one follower is positioned and movable in a single plane, and the arm of the other follower is positioned and movable in two parallel planes with the single plane therebetween.

Claim 21

The positioning device according to claim 20, wherein each of the followers includes at least one drive member and a vector sum of the moments of force at the

center of gravity of the object stage due to positioning forces of the cooperating drive members is substantially equal to zero.

Claim 22

The positioning device according to claim 20, wherein the center of gravity of the object stage is positioned in the single plane or adjacent to the single plane.

Claim 23

The positioning device according to claim 15, further comprising:

an object stage base;

a reaction frame assembly including a reaction frame mounted to the base structure;

means for supporting each of the followers from the reaction frame assembly; and

means for supporting the object stage from the object stage base with a gap therebetween, independently of the reaction frame,

whereby the object stage base and the object stage are isolated from vibrations created by reaction forces thereof, and therefore vibrations of the object stage base and the object stage are minimized.

Claim 24

An alignment device comprising:

(a) an XY stage having a center of gravity;

(b) means for supporting the XY stage from an XY stage base with a gap therebetween; and

(c) a reaction frame assembly including a reaction frame supported on a reaction frame base, independently of the XY stage base, wherein

(d) the reaction frame assembly includes an X follower which is independently movable and a Y follower which is independently movable, the X follower movably mounted to the reaction frame is movable in an X direction, and the Y follower movably mounted to the reaction frame is movable in a Y direction,

(e) one of the X follower and the Y follower includes at least two spaced-apart arms, and the other of the X follower and the Y follower includes at least one arm, the alignment device further comprising:

(f) a pair of cooperating linear actuator means provided in a spaced relation between the XY stage and each of the followers for positioning the XY stage in a horizontal direction and generating a force;

(g) the actuator means includes drive partial element means provided in the arm of each of the followers and drive main member means provided in the XY stage and cooperating with the drive partial element means to position the XY stage,

the XY stage base and the XY stage are isolated from vibrations created by reaction forces, whereby vibrations of the XY stage base and the XY stage are minimized.

Claim 25

The alignment device according to claim 24, wherein the one arm provided in any one of the X follower and the Y follower is movable in a single plane, and two arms which are the pair of the arms provided in another one of the X follower and the Y follower are positioned in two independent planes, respectively, with the single plane therebetween and are movable in the planes.

Claim 26

The alignment device according to claim 25, further comprising means including the drive partial element means provided in the pair of the arms of the one follower for controlling the same, wherein a vector sum of the moments of force at the center of gravity of the XY stage due to positioning forces of the cooperating drive main member means is substantially equal to zero.

Claim 27

A method for positioning an object, comprising the steps of:

(a) positioning a reaction frame on a base;

(b) supporting an object on an object stage;

(c) supporting the object stage in space at a certain position from an object stage base; and

(d) exerting a force between the object stage and the reaction frame to drive the object stage to a new position in space in at least one direction, and at the same time isolating the object stage base from reaction forces created by exerting the force.

Claim 28

A method for positioning an object stage in space by moving the object stage in a first direction and a second direction using at least a first follower and a second follower, comprising the steps of:

(a) supporting the object stage in space;

(b) exerting a force between the object stage and the first follower to drive the object stage only in the first direction;

(c) exerting a force between the object stage and the second follower to drive the object stage only in the second direction;

(d) driving the first follower only in the second direction independently of the second follower, so as to follow the object stage; and

(e) driving the second follower only in the second direction independently of the first follower, so as to follow the object stage.

Claim 29

The positioning device according to claim 1, further comprising:

means for mounting the actuator means between the object stage and the reaction frame, the mounting being rigid at least in a driving force direction.

Claim 30

The positioning device according to claim 15, further comprising:

means for mounting the actuator means between the object stage and each of the followers, the mounting being rigid at least in the driving force direction.

Claim 31

The positioning device according to claim 24, further comprising:

means for mounting the actuator means between the XY stage and each of the followers, the mounting being rigid at least in the driving force direction

Claim 32

A precise positioning device configured such that a base plate having a plane and a stage movable on the plane along a predetermined direction cooperate, comprising:

(a) a first support assembly for supporting the base plate on a foundation;

(b) an actuator assembly for exerting an electromagnetic force to the stage movable along the predetermined direction, the actuator assembly including (i) a movable driven section mounted to the movable stage and movable in the predetermined direction, and (ii) a driving section positioned around the movable stage, and (iii) one of the driven section and the driving section including a coil unit, and the other of the driven section and the driving section including a magnetic unit; and

(c) a second support assembly which supports the driving section on the foundation independently of the first support assembly, to thereby form a predetermined gap between the coil unit and the magnetic unit.

Claim 33

The precise positioning device according to claim 32, wherein the driving section of the actuator assembly is held at a stationary position with respect to the predetermined direction.

Detailed Description of the Invention

[0001]

Industrial Field of Utilization

The present invention relates, in general, to electro-mechanical alignment and isolation and, more particularly, to such a method and apparatus for supporting and aligning a wafer in a microlithographic system and isolating the system from its own reaction forces and external vibrations.

[0002]

Prior Art

Various support and positioning structures are known for use in microlithographic instruments. Typically, in the prior art, XY guides, including a separate X guide assembly and Y guide assembly, are utilized with one guide assembly mounted on, and movable with, the other guide assembly. Often, a separate wafer stage is mounted on top of these guide assemblies. These structures require high precision and many parts. Typically, external forces directed to parts of the positioning assembly and reaction forces due to movement of different parts of the positioning assembly are coupled directly to the image forming optics and reticle handling equipment resulting in unwanted vibration.

[0003]

U.S. Pat. No. 5,120,03 (Van Engelen et al.) discloses a two-step positioning device for an opto-lithographic device, and the positioning device uses Lorentz forces and a static gas bearing.

[0004]

U.S. Pat. No. 4,952,858 is directed to a microlithographic apparatus utilizing an electro-magnetic alignment apparatus and the electro-magnetic alignment apparatus including a monolithic stage, a sub-stage and isolated reference structure, in which force actuators imposed between the monolithic stage and the sub-stage are used for suspending and positioning the monolithic stage in space. In this apparatus a Y frame, that is, a Y stage is mounted on an X frame and the monolithic stage is positioned from and supported in space from the Y frame.

[0005]

Problems to Be Solved by the Invention

Broadly stated, the present invention is directed to a method and apparatus utilizing a guideless stage for supporting an object and incorporating a reaction frame which isolates both external forces as well as reaction forces created in moving the object from other elements of the system such as a lens system which produces an image that is exposed on the photoresist of a wafer object surface.

[0006]

Means to Solve Problems

The present invention incorporates an object stage, a reaction frame mounted on a base and substantially free from transferring vibrations between itself and the object stage, means for supporting the object in space independent of the reaction frame and a pair of cooperating linear actuator means mounted on the object stage and the reaction frame for positioning of the object stage and generating a force. The object stage can be mounted for movement in a given direction or can constitute an XY stage for movement in the X and Y directions while being supported in space in the Z direction.

[0007]

An advantageous aspect of the present invention is the provision of a support, positioning and isolation assembly which allows the positioning function of the object or wafer stage to be accomplished while minimizing vibrations coupled to the stage and lens systems from the reaction stage faster and with fewer parts while minimizing vibrations coupled to the stage and isolating the stage from undesired reaction forces.

[0008]

In accordance with another aspect of the present invention, a positioning method and apparatus are provided for an XY stage with an independently moveable X follower and independently moveable Y follower and cooperating linear force actuators mounted between the stage and followers whereby the movement of either follower does not interfere with the movement of the other follower.

[0009]

In accordance with another aspect of the present invention, a pair of arms are provided on at least one follower with each arm including a drive member and wherein the arms are positioned and movable in space-apart planes above and below the center of gravity of the object stage.

[0010]

In accordance with another aspect of the present invention, the guideless stage incorporates at least three linear force actuators with two of those actuators driving in one of the X or Y directions and the third actuator driving in the other of the X and Y directions. In accordance with the preferred embodiment of this invention, the guideless stage incorporates at least four linear actuators operating between the XY stage and a reaction frame assembly with each actuator including a drive member on the XY stage so that a pair of X drive members serve to drive the XY stage in an X direction for automatic control and a pair of Y drive members serve to drive the XY stage in the Y direction for automatic control. The linear actuators and their drive members are constructed, positioned and controlled such that the vector sum of the moments of force at the center of gravity of the XY stage due to the positioning forces of cooperating drive members is substantially equal to zero.

[0011]

These features and advantages of the present invention will become more apparent upon perusal of the following specification taken in conjunction with the following drawing wherein similar characters of reference refer to similar parts in each of the several views.

[0012]

Embodiments

While it will be appreciated by those skilled in the art that the guideless stage, with or without its isolating reaction frame, has many applications to many different types of instruments for precise positioning of objects, the present invention will be

described with respect to a preferred embodiment in the form of a microlitholigraphic instrument for aligning wafers in a system where a lens produces an image which is exposed to the photoresist on the wafer surface. In addition, while the guideless stage with or without its isolation stage can be utilized as a guideless object stage movable in just one direction, such as an X or a Y direction, the preferred embodiment of the invention is directed to a guideless XY wafer stage as described below.

[0013]

Referring now to the drawings, with particular reference to Figs. 1 to 5, a photolithographic instrument 10 is shown having an upper optical system 12 and a lower wafer support and positioning system 13. The optical system 12 includes an illuminator 14 including a lamp LMP, such as a mercury lamp, and an ellipsoid mirror EM surrounding the lamp LPM. And the illuminator 14 comprises an optical integrator such as a fly's eye lens FEL producing secondary light source images and a condenser lens CL for illuminating a reticle (mask) R with uniform light flux. A mask holder RST holding the mask R is mounted above a lens barrel PL of a projection optical system 16. The lens barrel PL is fixed on a part of a column assembly which is supported on a plurality of rigid arms 18 each mounted on the top portion of an isolation pad or block system 20.

[0014]

Inertial or seismic blocks 22 are located on the system so as to be mounted on the arms 18. These blocks 22 can take the form of a cast box which can be filled with sand at the operation site to avoid shipment of a massive structure. An object or wafer stage base 28 is supported from the arms 18 by depending blocks 22 and depending bars 26 and horizontal bars 27 (see Fig. 2).

[0015]

Referring now to Figs. 5 to 7, plan and elevation views are shown, respectively, of the wafer supporting and positioning apparatus above the object or wafer stage base 28, and the wafer supporting and positioning apparatus includes the object (wafer) XY stage 30 and the reaction frame assembly 60. The XY stage 30 includes a support plate 32 on which the wafer 34, such as a 12 inch (304.8 mm) wafer, is supported. The plate 32 is supported in space above the object stage base 28 via vacuum pre-load type air bearings 36 which can be controlled to adjust Z, i.e., tilt, roll and focus. Alternatively, in order to perform this support, combinations of magnets and coils may be employed.

[0016]

The XY stage 30 also includes an appropriate element of a magnetic coupling means such as a linear drive motor for aligning the wafer with the lens of the optical system 16 for precisely positioning an image for exposure of a photoresist on the wafer's surface. In the embodiment illustrated, the magnetic coupling means takes the

form of a pair of drive members such as X drive coils 42X and 42X' for positioning the XY stage 30 in the X direction and a pair of Y drive members such as drive coils 44Y and 44Y' for positioning the XY stage 30 in the Y direction. The associated portion of the magnetic coupling means on the reaction frame assembly 60 will be described in greater detail below.

[0017]

The XY stage 30 includes a pair of laser mirrors 38X and 38Y, the laser mirror 38X is operative with respect to a pair of laser beams 40A/40A' of a laser beam interferometer system 92, and the laser mirror 38Y is operative with respect to a pair of laser beams 40B/40B' of the interferometer system for determining and controlling the precise XY location of the XY stage relative to a fixed mirror RMX at the lower part of the lens barrel PL of the projection optical system 16.

[0018]

Referring to Figs. 8 and 9, the reaction frame assembly 60 has a reaction frame 61 which includes a plurality of support posts 62 which are mounted on the ground or a separate base so as to be substantially free from transferring vibrations between itself and the object stage.

[0019]

The reaction frame 61 includes face plates 64X and 64X' extending between support posts 62 in the X direction and 66Y and 66Y' extending between support posts in the Y direction. Inside the face plates 64-66 a plurality of reaction frame rails 67-69 and 67'-69' are provided for supporting and guiding an X follower 72 and a Y follower 82. Inside the face plate 64X are an upper follower guide rail 67 and a lower follower guide rail 68 (not shown) and on the inside surface of the opposite face plate 64X' are upper and lower follower guide rails 67' and 68'. On the inside surface of each of the face plates 66Y and 66Y' is a single guide rail 69 and 69', respectively, which is positioned vertically in between the guide rails 67 and 68.

[0020]

The X follower includes a pair of spaced-apart arms 74 and 74' connected at their one end by a cross piece 76. Drive elements such as drive tracks 78 and 78' (see Fig. 5) are mounted on the arms 74 and 74', respectively, for cooperating with the drive elements 42X and 42X' of the XY stage. Since in the illustrated embodiment, the drive elements 42X and 42X' on the XY stage are shown as drive coils, the drive tracks on the X follower 72 take the form of magnets. The coupling elements could be reversed so that the coils would be mounted on the X follower and the magnets mounted on the XY stage. As the XY stage is driven in the X and Y direction, the laser interferometer system 92 detects the new position of the XY stage momentarily and generates position information (X coordinate value). As described in greater detail below with reference to Fig. 10, a servo position control system 94 under

control of a host processor (CPU) 96 controls the position of the X follower 72 and the Y follower 82 in response to the position information from the interferometer system 92 to follow the XY stage 30 without any connection between the drive coils 42X and 42X' and the tracks 74 and 74'.

[0021]

For movably mounting the X follower 72 on the reaction frame 61, the ends of the arms 74 and 74' at the side of the reaction frame 61 ride and are guided on the rail 69, and the opposite ends of the arms 74 and 74' ride on the rail 69' adjacent to face plate 66 Y'. For moving the X follower 72, a drive member 77 is provided on the cross piece 76 for cooperating with the reaction frame rail 69 for moving the follower 72 in a direction which is perpendicular to the X direction of the XY stage. Since the precision drive and control takes place in the XY stage 30, the positioning control of the X follower 72 does not have to be as accurate and provide as close tolerances and air gaps as the XY stage 30. Accordingly, the drive mechanism 77 can be made of a combination of a screw shaft rotated by a motor and a nut engaged by the X follower 72 or a combination of a coil assembly and a magnet assembly to establish a linear motor and each combination can be further combined with a roller guiding mechanism.

[0022]

Similar to the X follower 72, the Y follower 82 includes a pair of arms 84 and 84' connected at their one end by a crossbar 86, and the arms include drive tracks 88 and 88' for cooperating with the Y drive members 44Y and 44Y'. The arms 84 and 84' of the Y follower 82 are guided on separate guide rails. Both ends of the arm 84 ride and are guided on the upper rails 67 and 67' and the both ends of the arm 84' are guided on lower rails 68 and 68'. A drive mechanism 87 is provided on the cross piece 86 of the Y follower 82 for moving the Y follower 82 along guides 67, 67', 68 and 68' between the face plates 66Y and 66Y' in a direction perpendicular to the Y direction of the XY stage.

[0023]

As best illustrated in Fig. 9, the arms 74 and 74' and crossbar 76' of the X follower 72 all lie within and move in the same plane crossing the Z axis. The center of gravity of the XY stage 30 lies within or is immediately adjacent to this plane. In this construction, the drive forces from each of the drive coils 42X and 42X' are in a direction along the length of the arms 74 and 74', respectively. However, the arms 84 and 84' of the Y follower 82 lie within and move in different parallel planes spaced apart along the Z axis from one another respectively above and below and parallel to the plane containing the X follower 72. In the preferred embodiment, the crossbar 86 lies in the lower plane containing the arm 84' and a spacer block 86' is positioned between the overlapping ends of the arm 84 and crossbar 86 to space the arms 84 and

84' in their respective parallel planes. As with X follower 72, the drive forces from each of the drive coils 44Y and 44Y' are in a direction along the length of the arms 84 and 84'. Also, predetermined gaps in X and Z directions are maintained between the drive coils 44Y (44Y') and the drive tracks 88 (88') to achieve the guideless concept.

[0024]

In operation of the guideless stage and isolated reaction frame of the present invention, the XY stage 30 is positioned in an initial position relative to the projection lens as sensed by the interferometer system 92, and the XY stage 30 is supported in the desired Z direction from the object stage base 28 by the air bearings with the drive coils 42X, 42X', 44Y and 44Y' spaced from the drive elements in the form of drive tracks 78, 78', 88 and 88', respectively. There is no direct contact between the XY stage 30 and the reaction frame 61. That is, there is no path for the vibration of the reaction frame to affect the position of the XY stage and vice versa. There is only indirect contact via the transmission means that delivers the signals to the coils and the laser interferometer position sensing system which then transmits sensed position information to the controller, that is, the control device, which receives other commands to initiate drive signals which result in movement of the XY stage 30.

[0025]

With the known position of the XY stage 30 from the interferometer system 92, drive signals are sent from the position control system 94 to the appropriate drive coils, 42X, 42X', 44Y and 44Y' to drive the XY stage to a new desired position. The motion of the XY stage is sensed by the interferometer system 92 and position sensors 98X and 98Y (see Fig. 10), and the X follower 72 and Y follower 82 are driven by the drive members 77 and 87, respectively, to follow the XY stage. As illustrated in Fig. 10, the position sensor 98X detects a variation of the Y direction space between the XY stage 30 and the X follower 72 and transmits an electric signal representing the amount of space to the position control system 94. The position control system 94 generates a suitable drive signal for the drive member 77 on the basis of the X position information from the interferometer system 92 and the signal from the position sensor 98X.

[0026]

Also, the position sensor 98Y detects a variation of X direction space between the XY stage 30 and the Y follower 82 and generates an electric signal representing the amount of space, and the drive member 87 is energized on the basis of the Y position information from the interferometer system 92 and the signal from the position sensor 98Y.

[0027]

Yaw correction is accomplished by the pairs of motors which can be used to hold or offset yaw. That is, the pairs of motors can change the rotational position of

the XY stage. The data from either or both pairs of laser beams 40A/40A' and 40B/40B' are used to obtain yaw information. Electronic subtraction of digital position data obtained from measurement using the laser beams 40A and 40A' or 40B and 40B' is performed or both differences are added and divided by two.

[0028]

This invention allows the positioning function of the XY stage to be accomplished faster than if XY guides were used. Reaction forces created in moving the XY stage can be coupled away from the image forming optics and reticle handling equipment.

[0029]

This invention needs no precision X or Y guides as compared to a guided stage, and an operation for precision assembly and adjustment of the wafer XY stage is reduced due to the lack of precision guides. The servo control bandwidth is increased because the linear motor forces in the XY axes act directly on the wafer stage; the linear motors do not have to act through a guide system.

[0030]

Forces from the XY linear motors can all be sent substantially through the center of gravity of the XY stage thereby eliminating unwanted moments of force (torque).

[0031]

With the X follower 72 and the Y follower 82 mounted and moved totally independently of one another, any vibration of a follower is not conveyed to the wafer XY stage or to the optical system when using commercially available electro-magnetic linear motors for the magnetic coupling between each of the followers 72 and 82 and the XY stage 30 and with clearance between the coils and magnet drive tracks less than about 1 mm. Additionally, with the arms of one of the followers spaced above and below the arms of the other follower, the vector sum of the moments of force at the center of gravity of the XY stage due to the positioning forces of cooperating drive members is substantially equal to zero.

[0032]

No connection exists between the XY stage and the follower stages that would allow vibrations to pass between them in the X, Y or θ degrees of freedom. This allows the follower stages to be mounted to a vibrating reference frame without affecting performance of the wafer stage. For example, if the reaction frame were struck by an obstacle, the XY stage and the projection optical system would be unaffected.

[0033]

It will be appreciated by a person skilled in the art that if the center of gravity is not equidistant between either of the two X drive coils or either of the two Y drive

coils, that appropriate signals of differing magnitude would be sent to the respective coils to apply more force to the heavier side of the stage to drive the XY stage to the desired position.

[0034]

For certain applications, the drive elements 42X/42X' or 42Y/42Y' of the actuator or magnetic coupling assembly for supplying electro-magnetic force to the movable XY stage may be held stationary (see Fig. 10) in a static position with respect to movement of the stage in either the X or Y direction, respectively.

[0035]

In the last of the explanations of this embodiment, referring to Fig. 4 again, the essential structure of the present invention will be described. As illustrated in Fig. 4, the XY stage 30 is suspended on the flat smooth surface (parallel with the X-Y plane) of the stage base 28 through the air bearings 36 having air discharge ports and vacuum pre-load ports and is movable in X,Y and θ directions on the stage base 28 without any friction.

[0036]

The stage base 28 is supported on the foundation (or ground, base structure) by the isolation blocks 20, arms 18, blocks 22, the vertical bars 26 and the horizontal bars 27. Each of the isolation blocks 20 is composed of a vibration absorbing assembly to prevent transmission of the vibration from the foundation 21.

[0037]

Since Fig. 4 is a sectional view of the XY stage 30 along a line through the drive coils 42X and 42X' in the Y direction, the following description is restricted to the X follower 72. In Fig. 4, the drive coils 42X are disposed in a magnetic field of drive track (magnet array elongated in the X direction) 78 mounted on the follower arm 74 and the drive coils 42X' are disposed in a magnetic field of the drive track 78' mounted on the follower arm 74'.

[0038]

The two arms 74 and 74' are rigidly assembled to move together in the Y direction by the guide rails 69 and 69' formed inside of the reaction frame 61. Also, the guide rails 69 and 69' restrict the movement of the two arms 74 and 74' in the X and Z directions. And the reaction frame 61 is directly supported on the foundation 21 by the four support posts 62 independently from the stage base 28.

[0039]

Therefore, the drive coils 42X (42X') and the drive tracks 78 (78') are disposed with respect to each other to maintain a predetermined gap (a few millimeters) in the Y and Z directions. Accordingly, when the drive coils 42X and 42X' are energized to move the XY stage 30 in the X direction, the reaction force generated on the drive tracks 78,78' is transferred to the foundation 21, not to the XY stage 30.

[0040]

On the other hand, as the XY stage 30 moves in the Y direction, the two arms 74 and 74' are moved in the Y direction by the drive member 77 such that each of the drive tracks 78 and 78' follows respective coils 42X and 42X' to maintain the gap in the Y direction on the basis of the measuring signal of the position sensor 98X.

[0041]

While the present invention has been described with reference to the preferred embodiment having a pair of drive members or coils 42X and 42X' and a pair of drive members or coils 44Y and 44Y', it is possible to construct a guideless stage with an isolated reaction frame in accordance with the invention with just three drive members or linear motors such as shown in Figs. 11 and 12. As illustrated in Fig. 11, a pair of Y drive coils 144Y and 144Y' are provided on the stage 130 and a single X drive coil or linear motor 142X is mounted centered at the center of gravity CG' of the XY stage. The Y drive coils 144Y and 144Y' are mounted on the arms 184 and 184' of a Y follower 182, and the X drive coil 144X is mounted on an arm 174" of an X follower 172. By applying appropriate drive signals to the drive coils 142X and 144Y and 144Y', the XY stage can be moved to the desired XY positions.

[0042]

Next, referring to Figs. 13 to 16, an alternative embodiment of the present invention is shown which includes links between the XY drive coils 242X, 242X', 244Y and 244Y' and the attachment to the XY stage 30'. These connections include a double flexure assembly 300 connecting the drive coil 244Y to one end of a connecting member 320 and a double flexure assembly 330 connecting the other end of the connecting member 320 to the XY stage 30'. The double flexure assembly 300 includes a flange 302 connected to the coil 244Y. A clamping member 304 is attached via clamping bolts to the flange 302 to clamp therebetween one edge of a horizontal flexible link 306. The other end of the flexible link 306 is clamped between two horizontal members 308 which are in turn integrally connected with a vertical flange 310 to which are bolted a pair of flange members 312 which clamp one edge of a vertical flexible member 314. The opposite edge of the vertical flexible member 314 is clamped between a pair of flange members 316 which are in turn bolted to a flange plate 318 on one end of the connecting member 320. At the other end of the connecting member 320, a plate 348 is connected to two flange members 36 which are bolted together to clamp one end of a vertical flexible member 344. The opposite edge of the vertical member 344 is clamped by flange members 342 which are in turn connected to a plate 340 connected to a pair of clamping plates 338 clamping one edge of a horizontal flexible member 336, the opposing edge of which is in turn clamped onto the XY stage 30' with the aid of the plate 334. Thus, in each of the double flexure assemblies 300 and 330 vibrations are reduced by providing

both the horizontal and vertical flexible members. In each of these assemblies, the vertical flexible members reduce X, Y and θ vibrations and the horizontal flexible members reduce Z, tilt and roll vibrations. Thus, there are eight vertical flex joints for X, Y and θ and eight horizontal flex joints for Z, tilt and roll.

[0043]

As illustrated in Fig. 16, the coil 244Y is attached to a coil support 245Y which has an upper support plate 246 attached thereto which rides above the top of the magnetic track assembly 288. Vacuum pre-load type air bearings 290 are provided between the coil support 245Y and upper support plate 246 on the one hand and the magnetic track assembly 288 on the other hand. In an operative example of the embodiment illustrated in Figs. 13 to 16, the flexible members 306, 314, 344 and 336 are stainless steel of about 31.8 mm (1 1/4 inch) wide, about 6.4 mm (1/4 inch) long and about 0.305 mm (0.012 inch) thick with the primary direction of flex being in the direction of the thickness. In the embodiment, illustrated members 306 and 314 are mounted in series with their respective primary direction of flex being orthogonal to one another; members 344 and 336 are similarly mounted.

[0044]

While the present invention has been described in terms of the preferred embodiment, the invention can take many different forms and the scope of the invention is only limited by the scope of the following claims.

<u>Brief Description of the Drawings</u>

<u>Fig. 1</u>

Fig. 1 is a perspective view of a microlithography system incorporating the present invention.

<u>Fig. 2</u>

Fig. 2 is a perspective view of a portion of the structure shown in Fig. 1 delineated by line A-A and with the reaction stage which is shown Fig. 1 removed.

<u>Fig. 3</u>

Fig. 3 is an elevation view, partially in section, of the structure shown in Fig. 1.

Fig. 1B is an elevation view, partially in section, of the structure shown in Fig. 1.

<u>Fig. 4</u>

Fig. 4 is a schematic elevation view, partially in section, of the object positioning apparatus of the present invention.

<u>Fig. 5</u>

Fig. 5 is a plan view of the wafer XY stage position above the reaction stage.

<u>Fig. 6</u>

Fig. 6 is a side elevation view of a portion of the structure shown in Fig. 5 taken along line 6-6 in the direction of the arrows.

Fig. 7

Fig. 7 is an enlarged view of a portion of the structure shown in Fig. 6 delineated by line B-B.

Fig. 8

Fig. 8 is a perspective view of the reaction stage showing the XY followers without the means coupled to the XY stage for positioning of the XY stage.

Fig. 9

Fig. 9 is an enlarged perspective view of the XY followers illustrated in Fig. 8.

Fig. 10

Fig. 10 is a schematic block diagram of the position sensing and control system for the preferred embodiment of this invention.

Fig. 11

Fig. 11 is a plan view similar to Fig. 5 of an alternative embodiment of the present invention.

Fig. 12

Fig. 12 is a side elevation view similar to Fig. 6, which shows the embodiment of Fig. 11.

Fig. 13

Fig. 13 is a plan view similar to Fig. 5 of still another embodiment of the present invention.

Fig. 14

Fig. 14 is a side elevation view similar to Fig. 6, which shows the embodiment of Fig. 13.

Fig. 15

Fig. 15 is an enlarged top view of a portion of the structure shown in Fig. 13.

Fig. 16

Fig. 16 is an end view of the structure shown in Fig. 15 taken along line 16-16 in the direction of the arrows.

Description of Symbols

| | |
|---|---|
| 10 | photolithographic instrument |
| 12 | optical device (optical system) |
| 28 | object stage base |
| 30 | XY stage |
| 34 | object (wafer) |
| 36 | air bearing |
| 42X, 42X' | X drive member (X drive coil) |
| 44Y, 44Y' | Y drive member (Y drive coil) |
| 60 | reaction frame assembly |
| 61 | reaction frame |

72 X follower
74, 74' arm of X follower
82 Y follower
84, 84' arm of Y follower

Fig. 10

30 wafer stage
42X $X_1$ drive coil
42X' $X_2$ drive coil
44Y $Y_1$ drive coil
44Y' $Y_2$ drive coil
72 X follower stage
77 drive coil
82 Y follower stage
87 drive coil
92 laser interferometer system
94 position control system
96 host CPU
98X position sensor
98Y position sensor